CONTENTS

# THE DEVELOPMENT OF SELF-HELP TRUSSES FOR RURAL HOUSES AND SERVICE BUILDINGS

By
Jerry O. Newman[1/]

## SUMMARY

Trusses have not been used extensively in rural house construction, because the demand in rural areas is usually not great enough to support a truss manufacturer and because suitable techniques have not been previously developed to allow a builder to make his own trusses. Through five generations of trusses, the techniques that will permit building uniform trusses onsite have progressively developed to the point that a builder can now prepare his jig and build his trusses, dismantle the jig, and then reuse the materials in the house.

Once the jig has been constructed, the builder can use unskilled labor to assemble the trusses. These trusses are stronger and lighter in weight than the conventional rafters and ceiling joists. If one uses self-help or unskilled labor instead of buying factory-built trusses, the overall cost can be reduced considerably. Analysis of the trusses in these tests indicates that it is possible to save $12 to $13 per truss.

## INTRODUCTION

The use of trusses for house construction in rural areas has lagged behind the techniques and economic advantages that result from this type of roof framing. The father-to-son and tradesman-to-tradesman method of training house builders has made the task of introducing proven techniques and methods into the house-building trade difficult. The use of trussed roofs is one improved building feature that has been accepted, but not widely used, in rural areas by small builders.

Truss factories have been established that build to custom-order or build and stock certain sizes of trusses depending on the demand in their local area. Many larger builders have used these ready-built trusses, because their market will allow them to pass the cost of truss construction on to their customers. Generally, the small builder has avoided the use of ready-built trusses because of the added cost, and he has not attempted to use self-help trusses because of lack of knowledge or information on truss construction.

This publication will show the development of a method of constructing trusses onsite, and it will also demonstrate the use of these trusses in several houses and small buildings.

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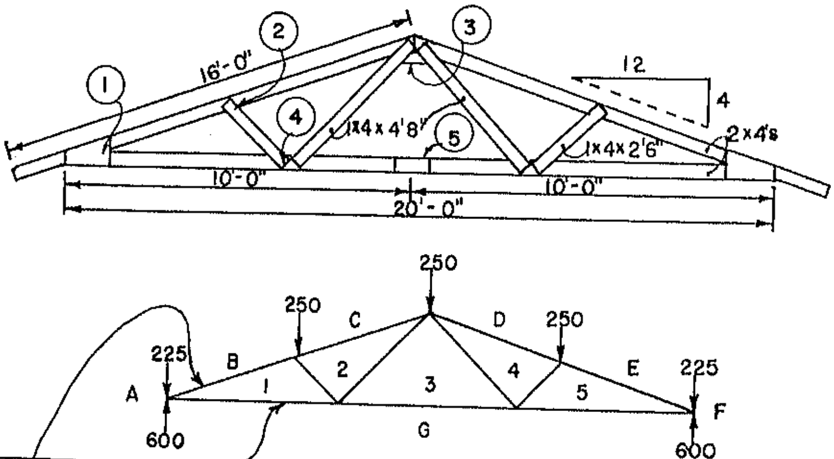
TRUSS DESIGN NO. 1

Figure 1 shows a 20' 0" truss designed for self-help construction.

## 20' TRUSS
## LAYOUT, CALCULATION AND NAILING SCHEDULE




| MEMBER | B·1 | C·2 | D·4 | E·5 | G·1 | G·3 | G·5 | 1·2 | 2·3 | 3·4 | 4·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FORCE | 1186 | 977 | 977 | 1186 | 1125 | 740 | 1125 | 270 | 263 | 263 | 270 |

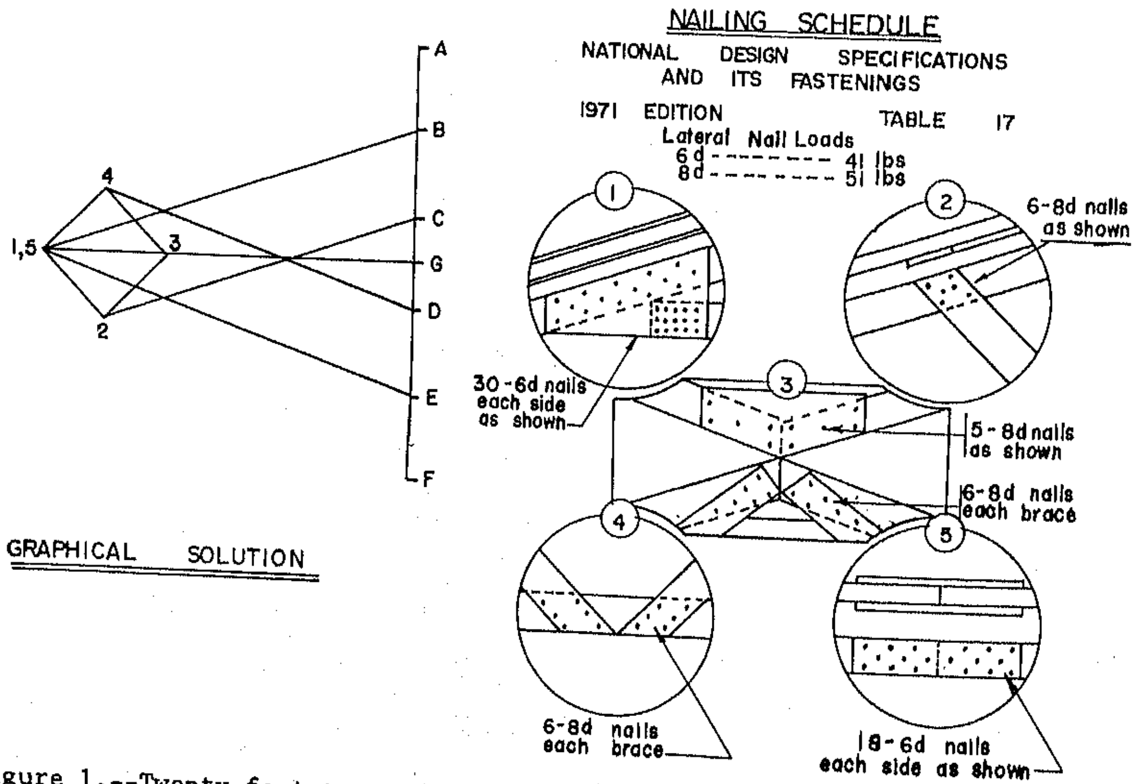



Figure 1.--Twenty-foot truss design, including graphical solution of stresses in truss member and nailing schedule.

The graphical solution for the designed load of 25 pounds per square foot of roof area or 50 pounds per linear foot of truss and the nailing schedule are shown. The resulting truss has 2 by 4[2/] compression legs and a 2 by 4 tension chord. The internal braces are 1 by 4's that overlap the 2 by 4 members.

Several steps were required in the development of satisfactory jigs and trusses. First, a jig was formed on the shop floor to hold the parts of the truss in place during nailing. The jig was built of 2 by 4's in an open lattice form to obtain the truss shape. Next, all parts of the truss were cut so that each joint would fit neatly together. The gusset plates were cut to the proper size and shape as shown in figure 1, and the internal braces were cut to the proper length and angle.

After all the members for a single truss were fitted into the jig, the internal braces and the gussets were nailed to the exposed side of the truss, thus securing the truss shape. The truss was removed from the jig, turned upside down, and laid on a flat surface. Then the gussets were nailed to the other side of the truss. Considerable difficulty occurred when the trusses were removed from the jig.

The jig had been built to a close tolerance that resulted in a tightly fitting truss. This made it necessary to lift the truss straight out of the jig without twisting or tilting. Because of accidental or unavoidable twisting, the jig was frequently pried and deformed while the trusses were being removed. After several trusses had been completed, it became necessary to repair and straighten the damaged jig.

The total number of nails used in each truss was 136: 36 were required in each of the two end gussets, 26 in the center gusset, 10 in the ridge gusset, and 28 in all the internal braces. Although considerable nailing time was required for each truss, persons who have unused or idle time could afford the minutes required to nail a truss together. A cost analysis (table) with lumber at $150 per 1,000 board feet[3/] shows the total cost of truss materials to be:

| | | | |
|---|---|---|---|
| Compression legs | 2 by 4 by 12' | 2 each @ $1.20 = | $2.40 |
| Tension chord | 2 by 4 by 20' | 2 each @ 1.00 = | 2.00 |
| Braces | 1 by 4 by 5' | 2 each @ .37 = | .74 |
| Braces | 1 by 4 by 3'6" | 2 each @ .27 = | .54 |
| Plywood gussets | 1/2 by 4 by 16 | 7 each = | .60 |
| Nails | 9/10 pound per truss | @ .50 = | .45 |
| Total cost | | | $6.73 |

2/ All dimensions will be in inches unless otherwise marked.
3/ Local, seasonal, or inflationary fluctuations in the price of lumber will all cause variations both in these data and in the resulting calculations; nevertheless, future calculations should produce proportional results. During the latter months of 1972, the cost of lumber was approximately $150 per 1,000 board feet.

The cost of a similar commercial truss is about $19. Therefore, approximately $12 per truss could be saved by using this self-help method, compared with buying commercially built trusses. A total of 20 trusses were constructed in this manner for use on the roof of the experimental pole frame shown in figure 2. Each truss requires a maximum of 45 minutes to cut and assemble; therefore, self-help labor is worth about $16 per hour.

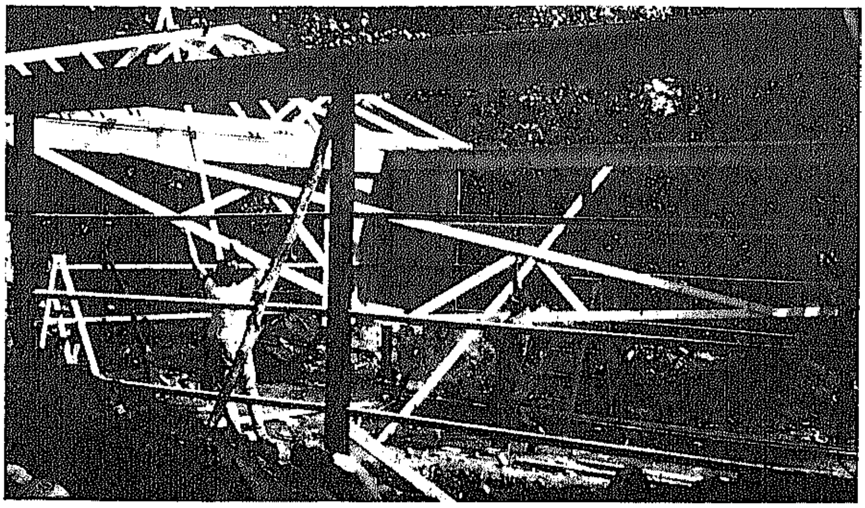


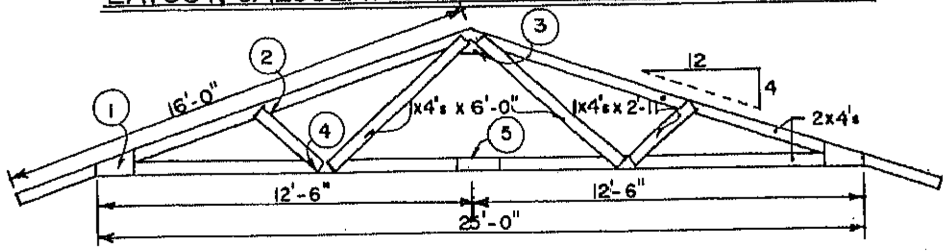
Figure 2.--Pole frame with 20' 0" trusses being erected into place.

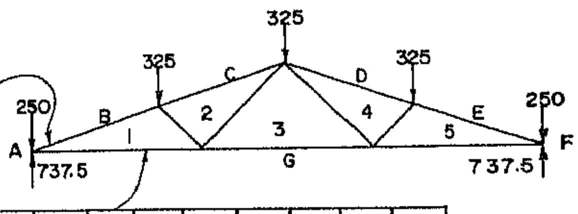
The trusses were lifted onto the pole frame, where they hung in an inverted position. The first truss was then tipped 180° into a vertical position and moved into place, then secured to the plates with nailed metal straps. The remaining trusses were then spaced 2 feet on center along the length of the building.

## TRUSS DESIGN NO. 2

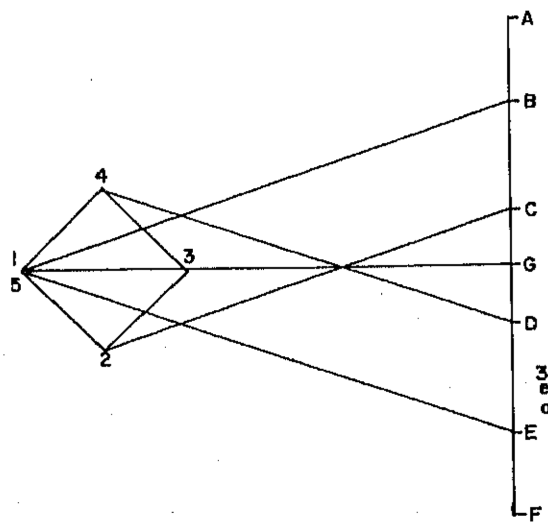
Truss No. 2 was a 25' 0" truss as shown in figure 3 built to fit a pole-frame house at Charles Town, W. Va. To overcome the problems encountered with the first jig, a second jig was built by preparing a solid plywood deck the length of the truss and as wide as the truss height (fig. 4).

### 25' TRUSS
### LAYOUT, CALCULATION AND NAILING SCHEDULE




| MEMBER | B 1 | C 2 | D 4 | E 5 | G 1 | G 3 | G 5 | 1 2 | 2 3 | 3 4 | 4 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FORCE | 1542 | 1270 | 1270 | 1542 | 1463 | 959 | 1463 | 354 | 345 | 345 | 354 |




GRAPHICAL SOLUTION

NAILING SCHEDULE

NATIONAL DESIGN SPECIFICATIONS AND ITS FASTENINGS

1971 EDITION TABLE 17

Lateral Nail Loads
6d -------- 41 lbs
8d -------- 51 lbs

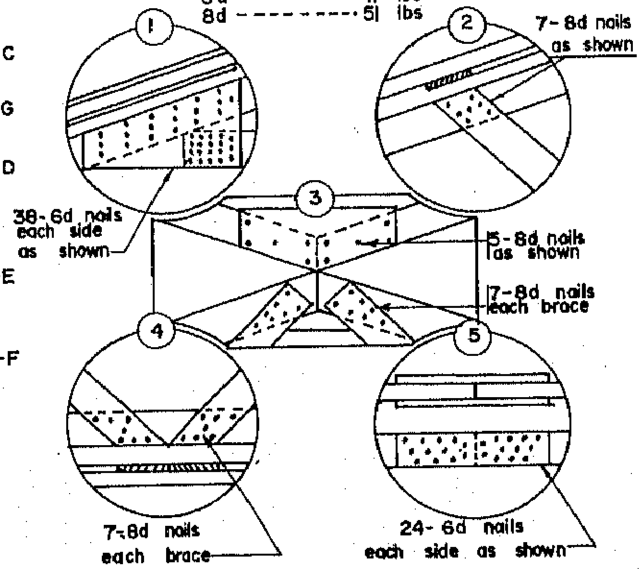



Figure 3.--Layout, load calculations, and nailing schedule for 25' 0" lightweight truss.

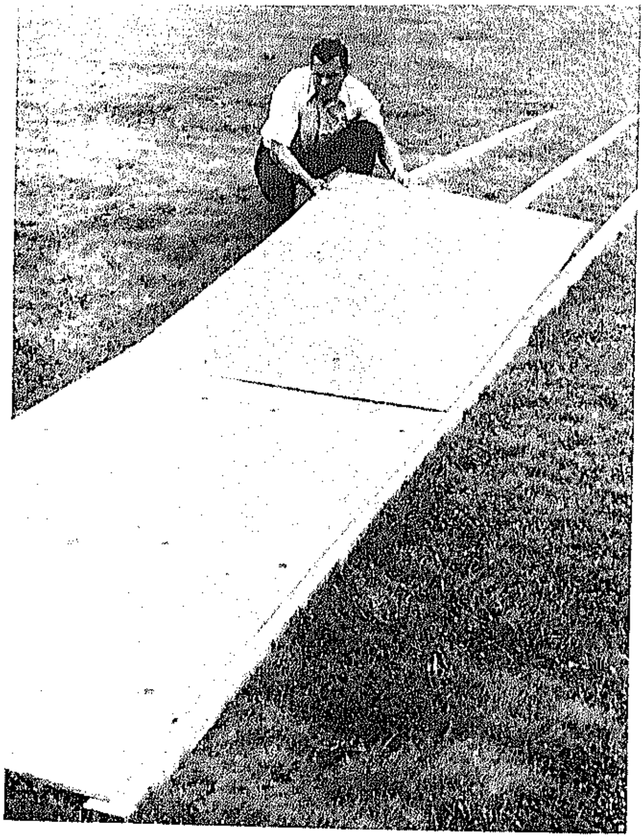


Figure 4.--Plywood deck being constructed as a base for building trusses.

The plywood deck was constructed by laying three 2 by 4's flat along the length of the deck and spaced 2 feet on centers (fig. 5) for securing the position of the plywood (fig. 6).

When trusses are taller than 4 feet, the plywood deck may be widened by adding plywood sheets on either side. The deck was prepared by using a minimum number of nails, so that it could be dismantled after the trusses were finished. The plywood and 2 by 4's could then be reused in the structure. This deck provided a rigid surface that did not shift during the truss construction and thus insure uniform truss shape.

The shape of the truss was laid out on the plywood deck (figs. 7 and 8). Then, short 2 by 4 blocks were nailed in place around the outer perimeter of the truss shape to fix the position of the truss-compression legs and its tension chord (figs. 9 and 10). It was easier to remove the assembled truss from the jig when short lengths of blocking were used instead of the long blocks that completely outlined the truss perimeter.

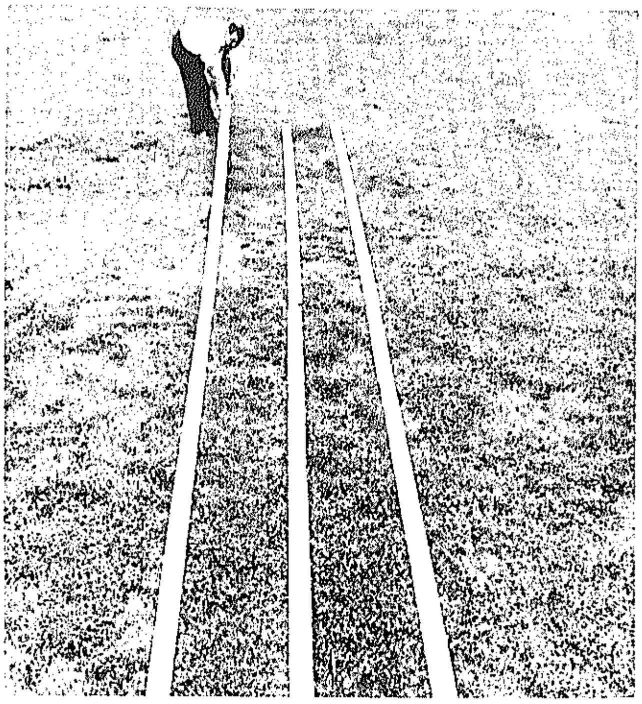


Figure 5.--Placing framing for plywood deck.

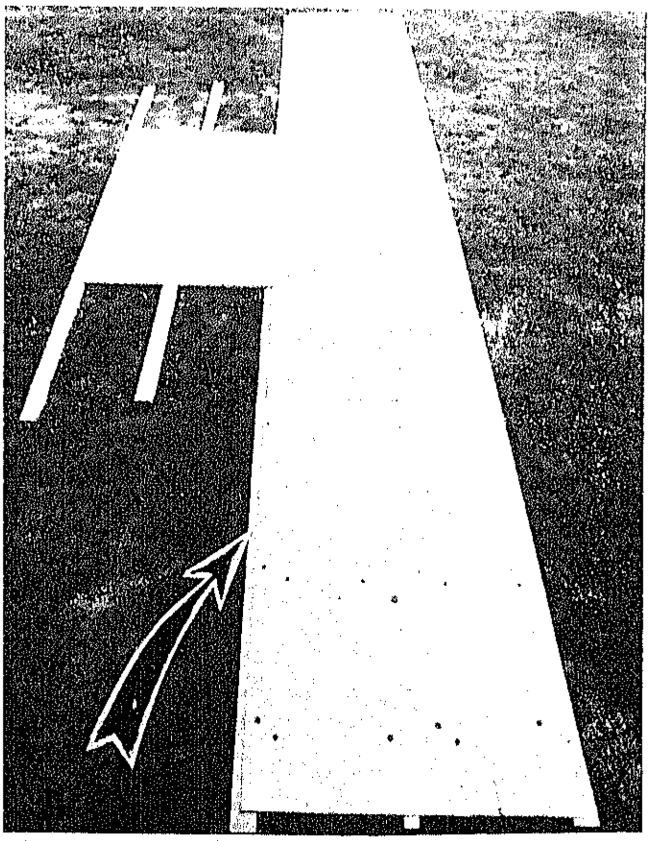


Figure 6.--Two by four framing members protrude at the edge of plywood for attaching additional width to deck.

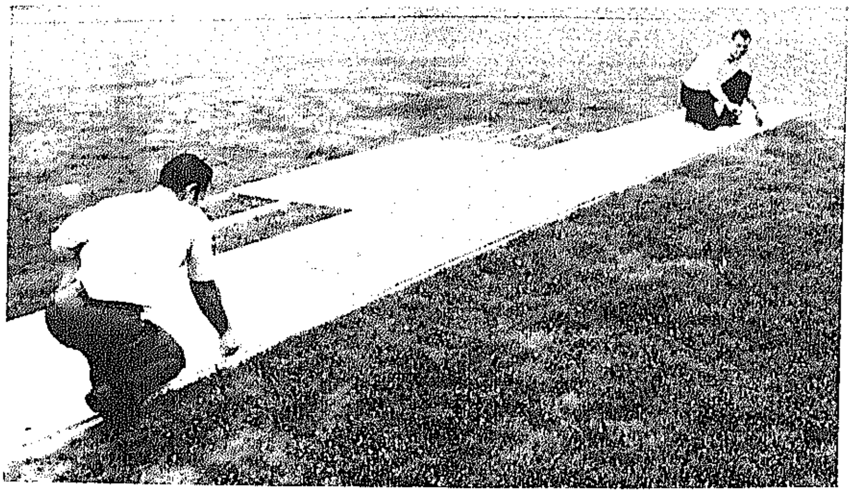


Figure 7.--Truss shape being laid out on the plywood deck. Bottom of truss is marked with a chalk line.

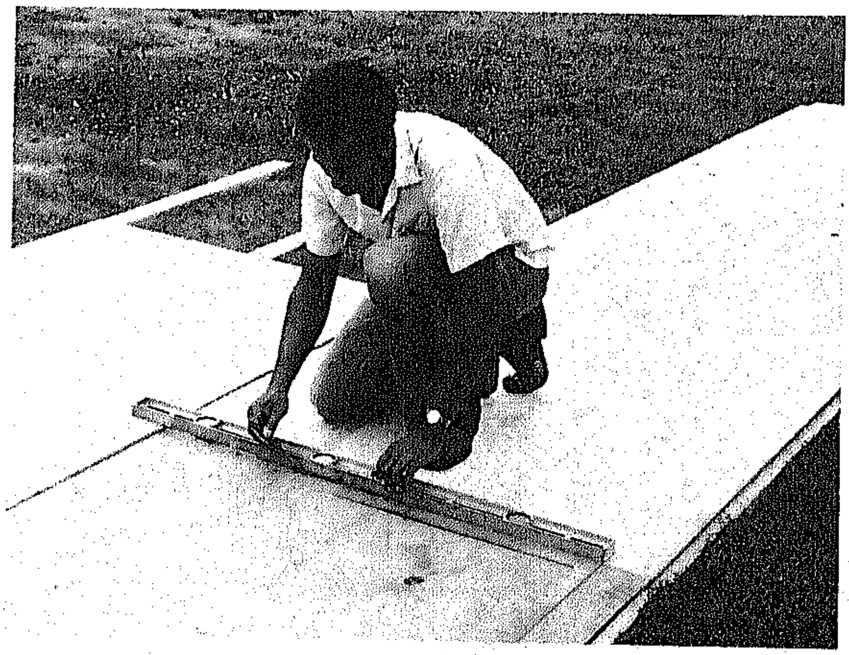


Figure 8.--The top of the truss is located by drawing a perpendicular to the bottom chord at its center.

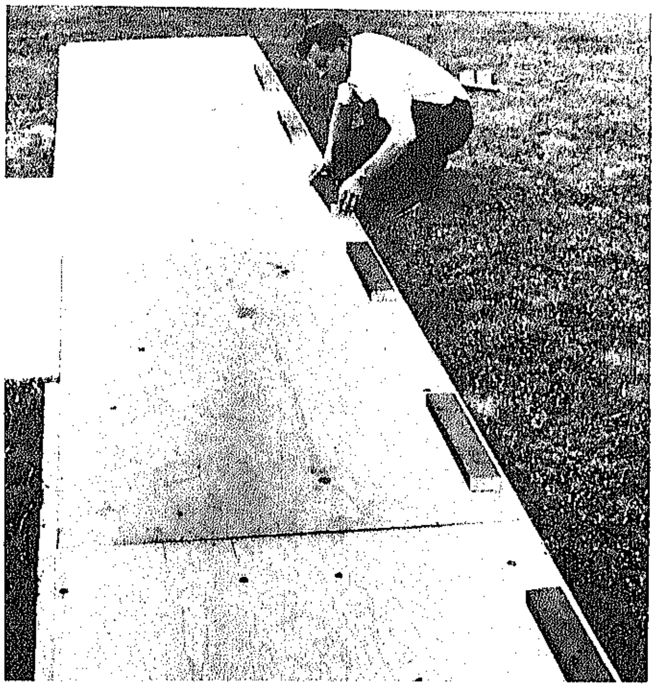


Figure 9.--Short blocks (2 by 4) were placed on the plywood deck to locate the bottom edge of the truss.

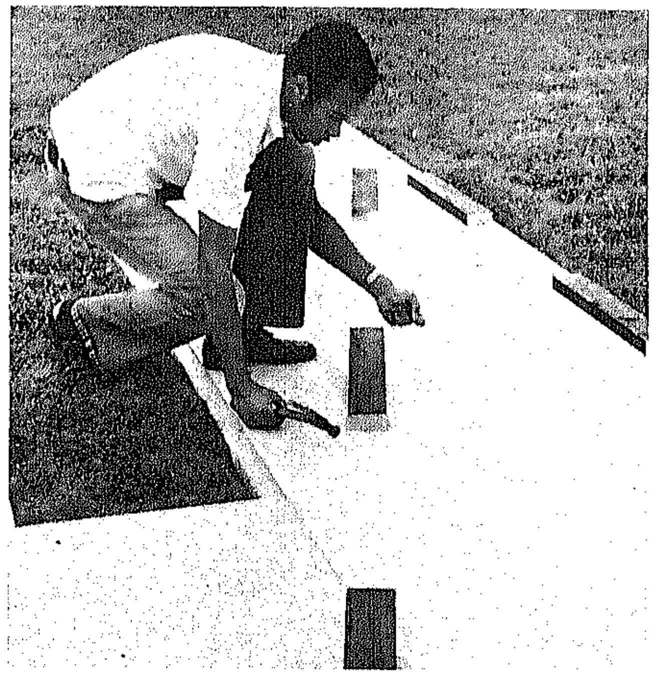


Figure 10.--Short blocks (2 by 4) were then fastened along the outer boundary of the top chord of the truss.

All truss members and braces were cut to length, and both ends were cut at the proper angle as shown in figure 5. Then a truss pattern (materials for one truss) was inserted into the jig and nailed together. Sixpenny (6d) nails were used to attach the 1/2-inch plywood gussets, while 8d nails were used to fasten the internal braces.

The completed trusses, inverted as described in the previous section, were carried to the plate. The only difference was that two 2 by 4 legs were attached to the ridge of the first truss (fig. 11). These legs extended from the top of the truss to a point on the ground about 5 feet on each side of the truss. These 2 by 4's were used as braces to hold the first truss in a perpendicular position and to secure it as a reference for installing the remaining trusses. The long 2 by 4 legs made it easy to adjust the reference truss to a plumb position.

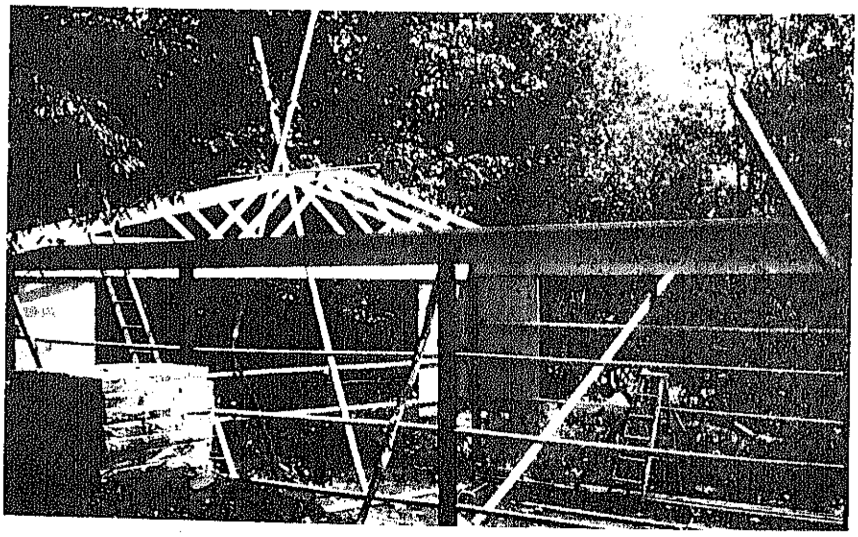


Figure 11.--Long legs made from 2 by 4's extend from the tops of the trusses to the ground to hold the truss in a vertical position.

When the trusses were in place, some irregularity in truss shape and warpage of truss members were often noticeable, but the trusses were acceptably straight.

The bill of materials for truss No. 2 was as follows:

| | | | | | |
|---|---|---|---|---|---|
| Compression legs | 2 by 4 by 16' | 2 each | @ $1.60 | = | $3.20 |
| Tension chord | 2 by 4 by 26' | 1 each | @ 2.60 | = | 2.60 |
| Braces | 1 by 4 by 7' | 2 each | @ .53 | = | 1.06 |
| Braces | 1 by 4 by 4' | 2 each | @ .20 | = | .40 |
| Plywood gussets | 1/2 by 4 by 16 | 7 each | | = | .60 |
| Nails | 1-1/2 pounds per truss | | @ .50 | = | .75 |
| Total cost | | | | | $8.61 |

Compared with a commercial truss cost of $21, this leaves approximately $12 for labor per truss.

A maximum of 45 minutes were required to cut and nail each truss. Thus, the self-help labor would again save approximately $16 per hour.

## TRUSS DESIGN NO. 3

Truss No. 3 was the same as truss No. 2. Only a few minor changes were made in its construction. There were no changes in the jig used for the No. 2 truss.

On this truss, the members were toenailed in the jig. This secured their position and straightened those 2 by 4's that were slightly warped. After the braces and gussets had been fastened in place, the toenails were removed, thus releasing the truss from the jig. Toenailing and straightening the timbers in the jig made the finished trusses uniform and produced an extremely flat surface for applying the roof deck.

In making truss No. 3, an airpowered nailer was used to save labor. Cutting and nailing time was reduced to approximately 20 minutes per truss, thereby engendering savings of about 25 minutes per truss. The cost of a power nailer is about $180, and the compressor needed to operate the nailer costs about $200. For self-help projects, this equipment might be rented to save labor.

A contractor who pays his labor $3 per hour would need to build 260 trusses to recover his $380 investment. This type of nailer can also be used for other nailing jobs, and the labor saved in only a few houses makes it economical to rent or purchase a power nailer for truss and house assembly.

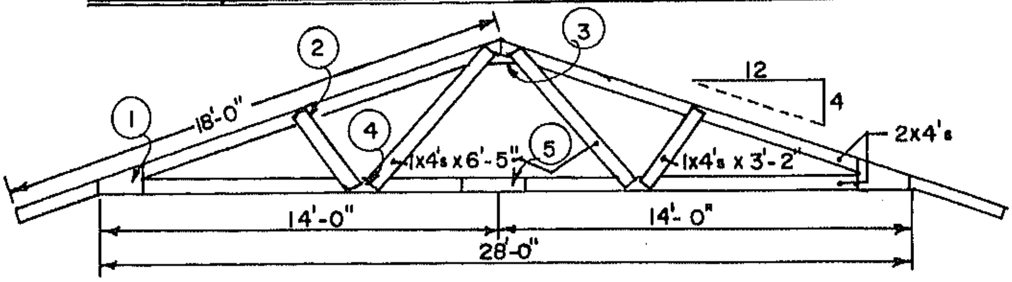
The ends of the internal braces of truss No. 3 were not cut to fit the slope of the truss as in the two previous trusses. The ends of these braces were cut square, thus reducing setup time and material. Since the same pattern was used, the cost of truss No. 3 would be the same as that of truss No. 2. The difference in nail cost is only slight. The 50-percent labor savings is the major improvement achieved in the third generation.

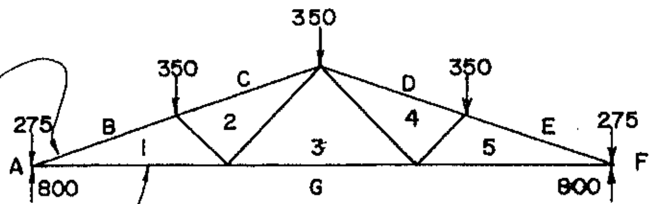
## TRUSS DESIGN NO. 4

Truss No. 4 was built for Prototype No. 3, a research house at Oakland, Md. This was a 28' 0" truss (fig. 12). The list of materials and their cost is as follows:

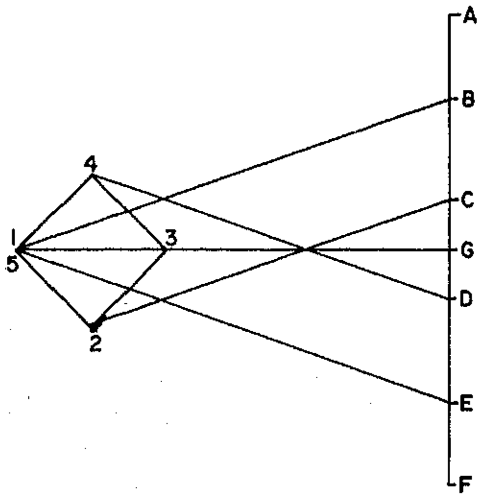
| | | | | |
|---|---|---|---|---|
| Compression legs | 2 by 4 by 18' | 2 each | @ $1.80 = | $3.60 |
| Tension chord | 2 by 4 by 28' | 1 each | @ 2.80 = | 2.80 |
| Braces | 1 by 4 by 7' | 2 each | @ .35 = | .70 |
| Braces | 1 by 4 by 3' | 2 each | @ .15 = | .30 |
| Plywood gussets | 1/2 by 4 by 16 | 6 each | = | .60 |
| Ridge gusset | | 1 each | = | .25 |
| Nails | 1-1/2 pounds per truss | | @ .50 = | .75 |
| Total cost | | | | $9.00 |

## 28' TRUSS
## LAYOUT, CALCULATION AND NAILING SCHEDULE




| MEMBER | B·1 | C·2 | D·4 | E·5 | G·1 | G·3 | G·5 | 1·2 | 2·3 | 3·4 | 4·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FORCE | 1660 | 1368 | 1368 | 1660 | 1575 | 1035 | 1575 | 380 | 367 | 367 | 380 |




GRAPHICAL SOLUTION

### NAILING SCHEDULE

NATIONAL DESIGN SPECIFICATIONS AND ITS FASTENINGS

1971 EDITION TABLE 17

Lateral Nail Loads

6 d --------- 41 lbs

8 d --------- 51 lbs

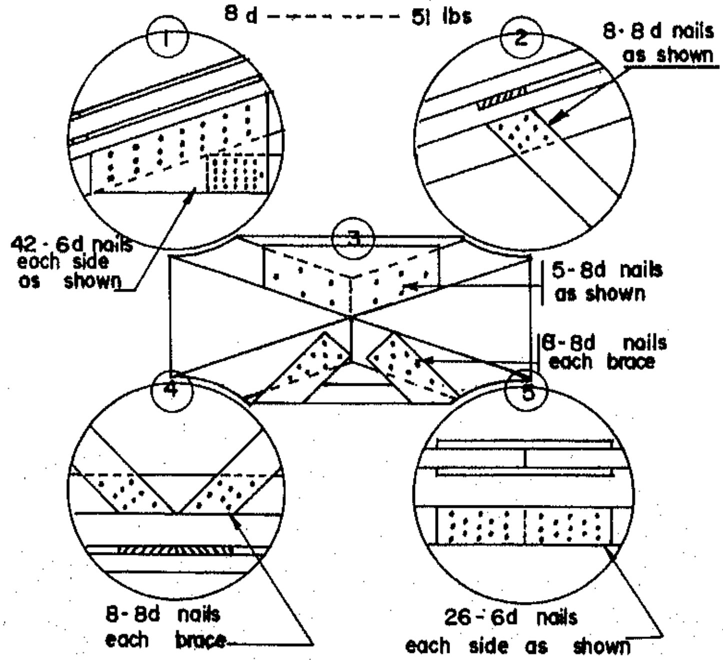



Figure 12.--Layout, graphical solution, and nailing schedule for truss No. 4, a 28' 0" lightweight truss.

The cost of a similar size commercial truss was $22; thus, a saving of $13 per truss was available for labor. A maximum of 20 man-minutes was required to build each truss when a power nailer was used. Thus, $39 per hour was saved through self-help labor. The charge for the power nailer must be deducted from this saving. Again, these trusses were small enough to be easily handled by two men.

The major change in this truss was that of using a 1 by 8 ridge gusset to increase the strength of that joint. This eliminated the need to cut the ends of the compression members at the ridge joint and allowed 2 by 4's with square-cut ends to be used. The ends of the tension chord member were cut to fit, because the angle was quite steep. If square-cut 2 by 4's were used for this timber, very large gussets would be required to insure adequate strength at this joint.

## TRUSS DESIGN NO. 5

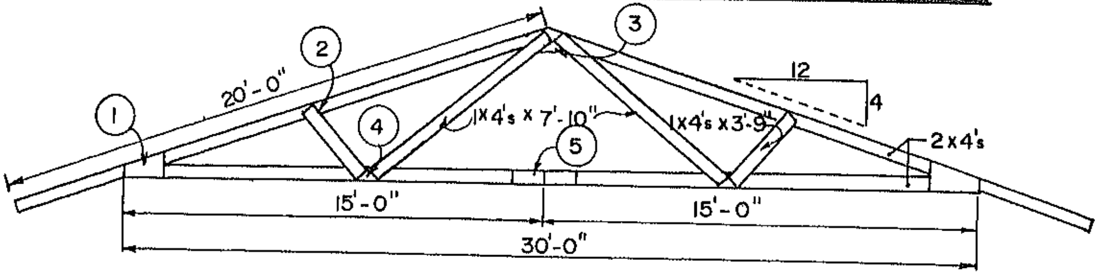
Truss No. 5 (fig. 13) was designed for a 30' 0" structure at Romney, W. Va. The list of materials and their cost is as follows:

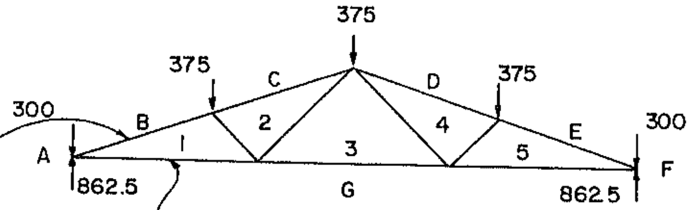
| | | | | |
|---|---|---|---|---|
| Compression legs | 2 by 4 by 18' | 2 each @ | $1.80 = | $3.60 |
| Tension chord | 2 by 4 by 30' | 1 each @ | 3.00 = | 3.00 |
| Braces | 1 by 4 by 8' | 2 each @ | .40 = | .80 |
| Braces | 1 by 4 by 3' | 2 each @ | .15 = | .30 |
| Plywood gussets | 1/2 by 4 by 16 | 2 each @ | .10 = | .20 |
| End-gussets | | 4 each @ | .30 = | 1.20 |
| Ridge gussets | | 1 each @ | = | .25 |
| Nails | 1-1/2 pounds per truss | @ | .50 = | .75 |
| Total cost | | | | $10.10 |

Several major changes were made to truss No. 5. The jig itself was improved by adding a series of blocks and wedges to straighten the truss members before nailing (fig. 14); the blocks and wedges made it possible to eliminate toenailing beginning with truss No. 3. Since the wedging operation is simpler and faster, the speed of construction was increased.

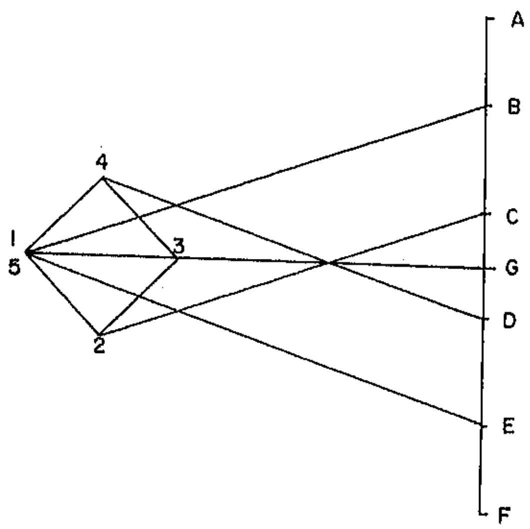
In the truss itself, several changes were also made. To avoid cutting the angles at the ends of the tension chord, larger gusset plates were used. These end-gussets were right-angled trapezoids in shape, 16 inches long at the base and 4 inches tall at the short end. They also increased in height along the slope of the truss. A slight increase in gusset cost improved the stability of the truss by making possible a better nailing and by eliminating the need to cut angles at the ends of the long tension chords. Short, wedge-shaped blocks (fig. 15) can be cut more easily with a table saw if one wishes to fill the space at the end of the square-cut tension chord to improve the bearing surface for the inplace truss.

# 30' TRUSS
## LAYOUT, CALCULATION AND NAILING SCHEDULE




| MEMBER | B1 | C·2 | D·4 | E·5 | G·1 | G·3 | G·5 | 1·2 | 2·3 | 3·4 | 4·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FORCE | 1779 | 1466 | 1466 | 1779 | 1688 | 1106 | 1688 | 408 | 400 | 400 | 40 |




GRAPHICAL SOLUTION

NAILING SCHEDULE

NATIONAL DESIGN SPECIFICATIONS AND ITS FASTENINGS

1971 EDITION TABLE 17

Lateral Nail Loads

6d ---------- 41 lbs

8d ---------- 51 lbs

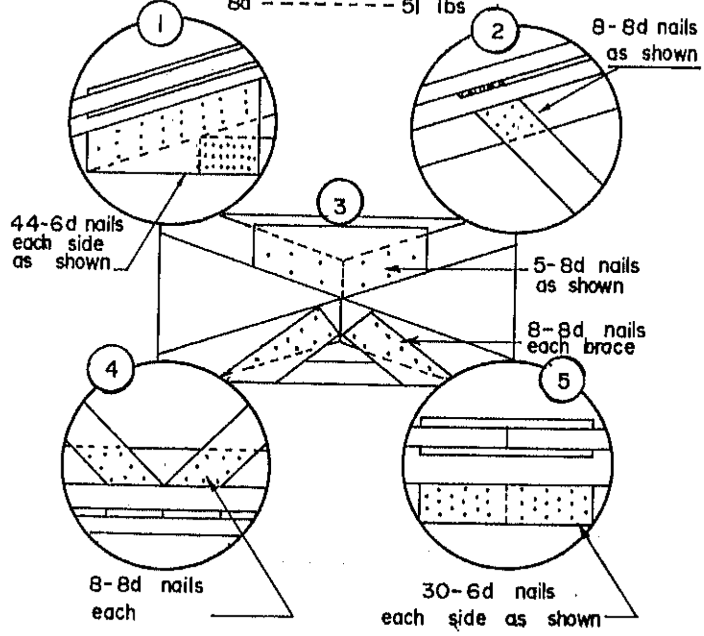



Figure 13.--Layout, graphical solution, and nailing schedule for truss No. 5, a 30' 0" lightweight truss.

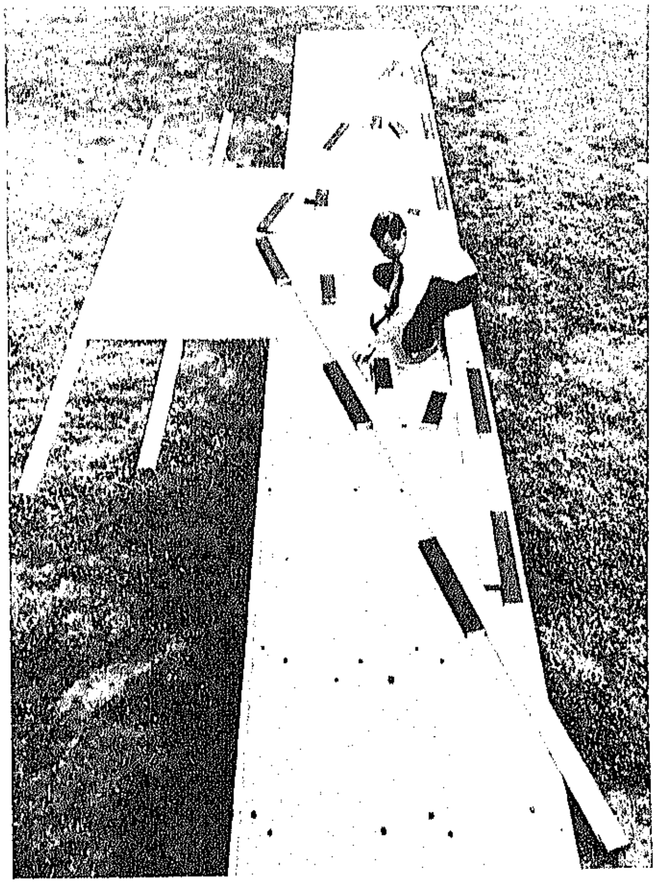


Figure 14.--Photograph of blocks and wedges being inserted to straighten truss members until truss shape has been fixed by nailing gussets and braces to it.

igure 15.--Short wedges cut by table saw to fit space at the end of the tension chord with square-cut ends.

## CONCLUSIONS

Each generation of self-help trusses has revealed new and improved techni and it is almost certain that future research will reveal further improveme However, at this point, the rural builder should be able to set up the jigs build his own trusses, thus improving his construction technique over rafte and joints and reducing his costs under those for factory-built trusses. T technique, as now developed, will allow a builder to use unskilled labor fo building trusses after skilled persons have prepared the jig and demonstrat the procedure.

Rural house construction practices have lagged behind urban construction practices because of the transportation costs and the scarcity of convenien items. More research on simplified procedures is needed to keep rural builders in pace with improved construction techniques.